

Interdisciplinary education in comprehensive school: Can a deep understanding occur?

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Abstract: The authors investigate how an integrative approach can be applied to teaching of different disciplines at school. Interdisciplinarity can be defined as a process of answering a question, solving a problem or addressing a topic that is too broad to be dealt with by a single discipline. In addition to an integrated understanding of the topic, the process going on inside the learner interests the authors. Unsuspected abilities, development of new views of the world and new commitment may emerge. Constructivism and narration, together with the socio-cultural theory of learning, form the background of the teaching and learning processes. The curriculum will integrate between subjects and recommends work in small groups to develop students' social capacities. The collaborative problem-solving approach, while including telling and re-telling features, allows students of natural sciences to hypothesize and test hypotheses using scientific methods. The target audience of this paper is class teachers and subject teachers in comprehensive schools (Grades 1-9). The research questions are: Do students that undergo integrative education work think and problem-solve in different ways compared to when partaking in standard instruction? Can they develop a deep understanding of the topic they are studying? The authors plan to present story re-telling and visualization activities in groups concerning one theme: eggs. The topic covers arts, foreign languages, mathematics and science. Such an approach strengthens students' understanding of the disciplines themselves. It is hoped that this work can be useful for teachers that are interested in giving their students a more holistic view of their life world.

Key words: curriculum; interdisciplinarity; integrated understanding

1. Introduction

An interdisciplinary field is a field of study that crosses traditional boundaries between disciplines, as new needs emerge (Anon, 2008, p. 4; Haynes, 2002). It involves students and teachers in the goals of connecting and integrating several perspectives of thought in the pursuit of a common task. Interdisciplinary approaches typically focus on problems thought to be too complex or vast for adequate understanding with the help of a single discipline. The global warming, for example, requires the understanding of diverse disciplines (Ranaweera, 1990,

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p. 21). The adjective interdisciplinary is often used in educational circles when subject teachers of 2 or more disciplines pool their approaches and modify them so that they are better suited to the problem at hand, including the case, where students are required to understand a given subject in terms of multiple traditional disciplines (Haynes, 2002). In a sense, interdisciplinarity may involve attacking a subject from various angles and with different methods, cutting across disciplines and forming a new method for understanding the subject (Anon, 2008, pp. 3-14). A common goal of understanding unites the various methods and acknowledges a common or shared subject or problem (Haynes, 2002).

Papadopoulou and Christidou (2004) suggested an interdisciplinary approach aiming at development of students' conceptual understanding and familiarizing students with different modes of representation of an issue. As texts become increasingly multimodal, information is derived, not only from the linguistic content, but also from visual, spatial or audile communication and representation. The need to manage multimodal texts entails a pedagogy that builds on the capacity to understand and manage pictures, icons, plans, diagrams, tables, etc.. The aim of the presented program is to facilitate young students' understanding of the problem of water scarcity (Papadopoulou & Christidou, 2004).

Holubova (2008) found that best results in teaching interdisciplinary relations are achieved by solving interdisciplinary projects. Students use a wide range of tools such as videos, artworks, reports, photography, music, live performance, digital stories and websites to produce evidence of what they have learned. Mills and Treagust (2003) suggested that students taught by project-based learning gain a less complete mastery of fundamentals than conventionally taught students acquire. This is not confirmed by the results of Holubova, however, she found that teachers are not able and willing to prepare interdisciplinary projects and collaborate (Holubova, 2008).

A disintegration of learning as resulting from integration of subject areas has been noted in primary schools in Quebec (Lenoir, Larose & Geoffroy, 2000). Primary school teachers adopt an approach based on empirical groping characterized of pluridisciplinarity. This tends to make-believe that simple proximity of subject areas is sufficient to establish an interdisciplinary activity. However, each subject area should have a definite and complementary place and function within the curriculum. There are specific methods pertinent to different scientific disciplines, which are called upon in an interdisciplinary approach (Lenoir, Larose & Geoffroy, 2000).

2. The project

In the following, the authors consider the instructional situation as a system that is described by the curriculum, instructional means and tools, and students and teacher colleagues. These form the answer to the ontological question "What is?", i.e., they describe the context in which learning takes place. The concepts of knowledge and learning describe the epistemological aspect of the instructional situation. The action system in this study is the instructional situation in Finnish comprehensive schools.

The research questions are that: Do students that undergo integrative education work think and problem-solve in different ways compared to when partaking in standard instruction? Can they develop a deep understanding of the topic they are studying? The authors present story re-telling and visualization activities in groups concerning one theme: eggs. Why this theme? Creation myths commonly describe how the universe was hatched from an egg, often laid by some mythical water bird swimming in the primordial waters. Both the sun and the egg have been viewed as the source of all life. The topic covers a wide range of subjects, i.e., arts, foreign languages, mathematics and science. Such an approach strengthens the students' understanding of the disciplines

themselves and their places in a larger system.

The project group consists of 6 persons connected to teaching and/or education research and it is working on a voluntary basis. Teachers perform action research of their own teaching. Observation and video recordings of lessons are used for data collection. Students' documentations and reviews that are used for assessment also give useful information. Each teacher plans and performs a lesson concerning the theme. The result is documented. All documents are presented to form a unity as a collage. At this stage, both teachers and students may formulate their own stories about the egg.

3. Documentation

The different stories developing from the collage raise questions about learners' thinking and learning strategies. It is the nature of relations among symbols that converts the medium into a message (Edwards, Gandini & Forman, 1998). In languages, sounds and words create a meaning; here combinations of materials from different disciplines form a collage of phrases or fragmented stories. The learners have an opportunity to construct a whole system from subsystems.

The curricular system is the instructional situation as expressed in the interactive discourse. The systemicity is epically-dynamic (Boje, 2006) and includes deviation-amplifying telling. The epic theory suggests that stories form clusters that are intertextually connected across place and time. The themes found are categorized. Within limits of the temporal form, the authors can consider these categories all at once (Denzin, 2001). Through the presentation of the collage in a form of a meta-story with a commentary, the researcher now becomes a storyteller herself (Kostera, 2006, p. 21). The final text is directed at the readers, who interpret it. The relevance of the stories crystallizes around foci of attention (Franck, 1998). These foci of attention are attractors for the stories processed inside the system. "The states of any system that do occur again and again, or are approximated again and again, more and more closely, therefore belong to a rather restricted set. This is the set of attractors" (Lorenz, 2001, p. 41).

4. Story fragments

In the next section, the different perspectives presented by distinct teachers are described. As defined, in a collage the order of the contributions does not matter. Only the fragment "a foreign language" has to be the last one as it ties together with the other fragments to a whole.

4.1 Art and religion

Egg was used in old times when people mixed their paints. Egg-tempera consists of powder pigment, egg yolk as binder and water as solvent. Tempera paints have been used to paint canvas, wood panes and secco (dry stone wall). Serious icon painters still mix their paints using yolk as binder. So why not let pupils try to mix their own tempera?

Colors are more stable in egg tempera paintings than in oil paintings. It is important to learn how to control the amount of mixed egg in the tempera. Painting will crack if there is too much egg in the tempera. Paint will be erased from the painting if there is too little egg in the tempera. The principle is still to "paint with different concentrations", i.e., first layers must contain more water and less egg than the later layers. Concentration of egg goes up, as the painting is built layer by layer. More eggs should be used on last layers.

Characteristics of the egg tempera are following: The paint should not be glossy as it dries up, it should also stay on the painting when the surface is touched by hand. The color should be matt and stable after it has dried up.

To prepare an egg emulsion:

(1) Separate egg yolk from egg white without breaking the yolk;

(2) Take the yolk in to your palm and shift it from palm to palm in order to separate the egg white (see Figure 1). The surface of the yolk should be broken as the yolk starts to fasten on the palm. The yolk is passed in to a clean jar;



Figure 1 Separating egg yolk from white

(3) Equal amount of water is added to the yolk with three drops of vinegar (conservative which breaks the fatty molecules in egg yolk in addition to conserving the paint). Emulsion should be stored in a cool place in a sealed jar.

Color pigments are mixed in water so that thick color slurry is formed. It is stored in a sealed jar. Color slurry is mixed with thick egg emulsion as the painting starts.

Wood pane can be primed with a mixture of water and egg yolk before painting: 1 part egg emulsion and 3-4 parts of water. Priming is done with a moist thick brush with light brushes.

Tempera colors dry up very fast and turn matt as they dry up. Colors must be spread fast as the drying process is fast. Painting should be done in several layers. Changes and corrections are done in following layers, and so on.



Figure 2 Icon painting by a student (after model)

Note: Photo: Natalie Klötzer, <http://www.steiner.fi/aktuellt/ikoner/>.

In the Rudolf Steiner school in Helsinki, students from Grade 8b with their teacher Lena Lietepohja and guided by the icon painter Antti Narmala from the Valamo orthodox monastery were painting an icon using egg tempera colours. Each colour has its own symbolic value. The project connects to religious teaching in the Orthodox Church (see Figure 2).

4.2 Biology

Reproduction is one of the most characteristic features of living organisms. Life would not exist on earth if plants and animals did not reproduce to make their offspring. By reproducing, a living organism can be sure that there is another individual of its kind to take its place when it dies. Animals can be grouped into those, which give birth to living offspring and those, which lay eggs that eventually hatch into offspring (see Figure 3). Young students find many opportunities for observation of birds and their living space. The nests and eggs of birds have always raised the interest of prospective investigators. However, not always one comes to think about that there are other animals than birds that lay eggs. Even there are some egg-laying mammals.

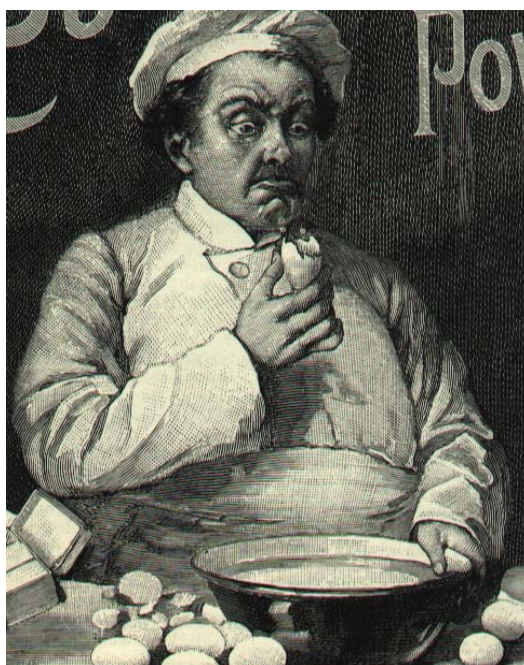


Figure 3 What surprise is there in the egg?

4.3 Mother tongue

During mother tongue lessons, the students wrote essays over the following topics:

- (1) An Easter egg hunt;
- (2) A nest egg—in concrete and transcribed sense;
- (3) The story of a Faberge egg.

The teacher supplied some information about the different topics. The intention, however, was that students can collect additional information from the web or from encyclopaedias.

A nest egg is a natural or artificial egg placed in a bird's nest, to encourage the bird to lay its own eggs there. It can also mean savings, a fund of money accumulated as a reserve.

Easter eggs are specially decorated eggs given out to celebrate the Easter holiday or springtime. The oldest tradition is to use dyed and painted chicken eggs, but a modern custom is to substitute chocolate eggs or plastic

eggs filled with confectionery such as jellybeans. These are often hidden, supposedly by the Easter Bunny, for children to find on Easter morning.

Another orthodox tradition is the presenting of red colored eggs to friends while giving Easter greetings.

The renowned Russian artist and jeweler Peter Carl Fabergé made exquisitely decorated precious metal and gemstone eggs for the Russian Court. These Fabergé eggs resembled standard decorated eggs, but they were made from gold and precious stones.

4.4 History and physics

The concept of Columbus' egg denotes a detection that seems obvious as soon as someone else has made it. It is connected to an anecdote. When Columbus had discovered America, a Spanish nobleman said that anyone could have done this. Columbus then asked if he could get an egg to stand on its top. The nobleman tried and was unsuccessful; then Columbus took the egg and knocked it against the table so that the top became stable. The nobleman said: "But this everyone could have done". Columbus answered: "Yes, when someone has shown how".

When you as a tourist visit the equator, it is fascinating to put an egg to stand on its top exactly on the equator. It is said to stay in this position. Why? Fact or fiction?



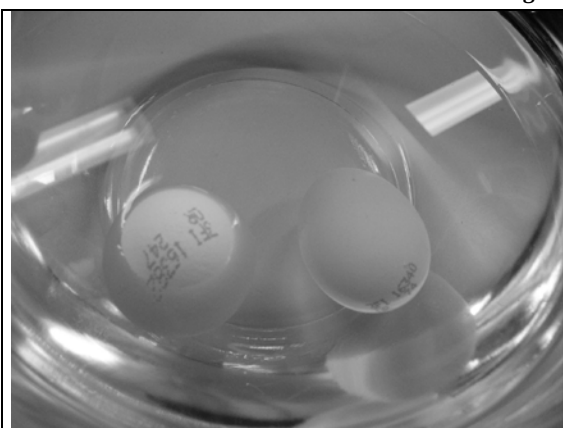
Figure 4 George III at breakfast

The famous English king George III had disheveled habits. Among the many satiric pictures of him that exists the one showing him eating an egg, it is very well known (here a front picture on a historic magazine is shown in Figure 4).

4.5 Home economics

Table 1 shows a learning episode in home economics.

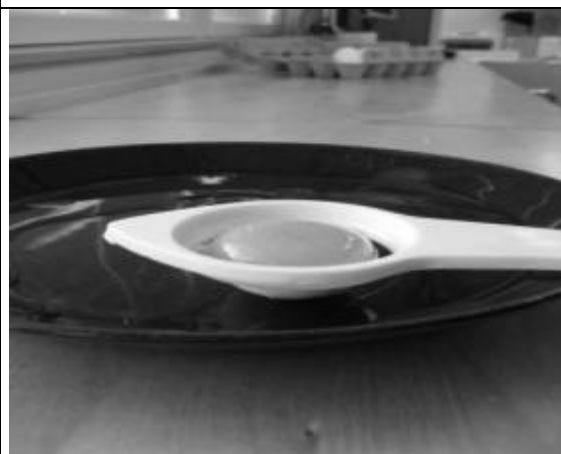
Table 1 Learning about eggs in home economics



How do you know if an unboiled egg is fresh or old? Answer: A fresh egg cannot swim.



An old egg floats apart (the white and the yolk) when it is cracked. A fresh egg forms layers and the white and yolk stay together.



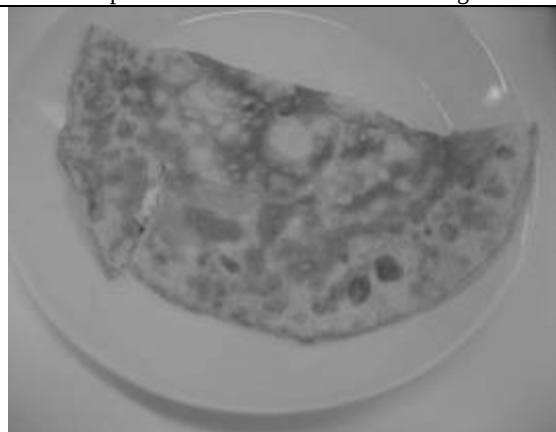
Of the egg both the white and the yolk can be used apart. Then they must be carefully separated.



The white is whipped to hard foam when you can turn the bowl upsidedown without the white running out.



A loosely boiled egg (boiling time 5 min) and a hard boiled egg (boiling time 10 min).



From eggs you can make good omelettes.

4.6 Mathematics

Geometrical construction which was developed in ancient Greece constitutes the foundation of mathematics (Euclid $\approx$ 300 before Christ). The present curriculum for geometry in comprehensive schools contains almost no

construction of geometrical figures. It is, however, thrilling for students to realize that use of only a ruler and compasses allows the construction of rather complicated figures, like eggs. Creation of geometrical patterns of different kinds out of simple elements develops both artistic and logical talents. Patterns appear in games and puzzles. They can be sequential, spatial, temporal and even linguistic. Mathematics can be described as the science of patterns. Patterns not only take many forms over the range of school mathematics, are but also a unifying theme.

How to construct an egg:

- (1) Draw a circle with O as centre;
- (2) Draw a diameter ending in A and B;
- (3) Draw the normal to AB through O;
- (4) The point of intersection with the circle is called C;
- (5) Draw the ray AC;
- (6) Draw the ray BC;
- (7) Draw a circular curve with A as centre and AB as radius;
- (8) The intersection between the circular curve and the ray AC is called D;
- (9) Draw a circular curve with B as centre and AB as radius;
- (10) The intersection between the circular curve and the ray BC is called E;
- (11) Draw a circular curve with C as centre and CD as radius between the rays AC and BC.

The egg is ready!

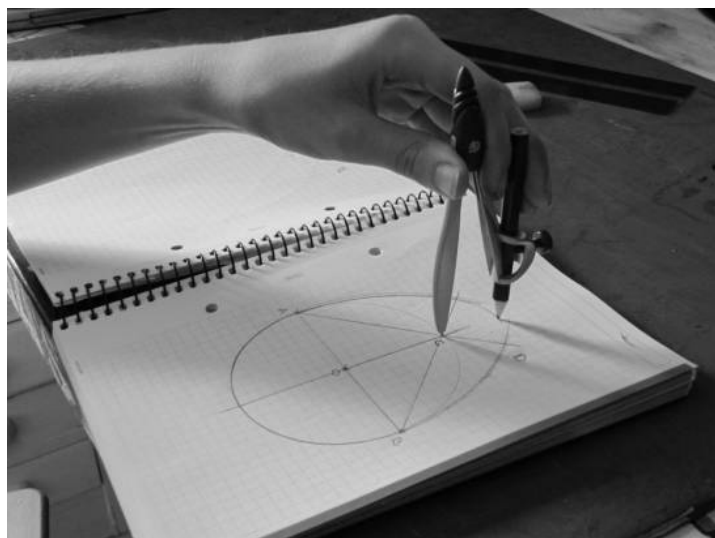


Figure 5 A student constructs an egg

This geometrical exercise can be used when training to draw circles (see Figure 5). The story of Archimedes' death offers an interesting historical background (Noli turbare circulos meos; do not disturb my circles!).

4.7 Art and geography

One example of people's struggle to understand the world around people is evident in their understanding of the shape of the earth itself. The students build a miniature model of the globe in this art project (see Figure 6). They use egg shells that have been painted in different colours and are glued on a ball made of paper mass. Eggshells build a mosaic pattern on the ball. Different colours represent different continents on the globe.

Eggshells have been chosen to connect the work with the national epos Kalevala. Pupils learn to know Kalevala in the school in addition to other stories that describe how the world has been created from an egg.

The end result can be a realistic picture of the globe, a historical reflection of it, a futuristic view or an imaginary picture of the globe. Every result is acceptable and as good as any other.



Figure 6 The globe

This exercise supports also educational purposes for geography. Students learn in a concrete way that the axis of the globe is not vertical. They will also realize in practise the difference between a flat map and a globe.

The exercise is easy to understand but demanding in practise. It is therefore recommended for pupils older than 12 years. In Figure 6, a picture sequence from the work of a group of students is shown.

4.8 Native-level language

The teacher's instruction to her students (given in the native-level language) goes as follows:

(1) The teacher will give students a picture of some animal's egg. The task is to find knowledge about it by using nonfiction literature and Internet: (a) The students should collect a good package of knowledge; and (b) They should create a vocabulary of five central concepts, where they explain the meaning of the concepts in their mother tongue.

(2) The students should write an essay (in the native-level language) about 150-200 words long concentrating on the sort of egg they investigate. They should use the knowledge they have found and the central concepts: The essay may be nonfiction or fiction.

(3) The students should create a normal mother tongue—native-level language vocabulary from their essay.

(4) The students should gather their research material, the essay and the vocabulary to a neat package, which they return to the teacher.

There are four 45-min lessons reserved for the work. Of these at least one should be spent in the computer class. The students should take care to record and retain their material.

An excerpt from a student essay:

... In the screening the egg's yolk, white, and the size of the airspace were controlled. Old, spoiled or dirty eggs were thrown away. The egg of the Big Egg-Mother (hen) passed the screening easily, because it was a perfect egg. Accepted eggs were marked, weighted, and packed in cardboard cells, on which information about the henhouse was printed. The ready egg cells were sent to shops all around Finland.

The egg cell, in which the perfect egg of Big Egg-Mother was, was brought to a big commercial center. In a nearby upper secondary school, the student and athlete Pelle-Iivari in a break went to buy himself a healthy and muscle breeding snack. In the shop, Pelle-Iivari went directly to the egg shelf and chose an egg cell, in which was the egg of Big Egg-Mother. After school, Pelle-Iivari run home with the egg package in his bag. At home he started immediately to prepare an omelet and took from the egg cell the first good-looking egg, or the egg of Big Egg-Mother, and broke it into the frying pan. Omelet was Pelle-Iivari's favorite meal, because egg contains lots of protein, which breeds muscles and healthy fatty acids, which are vital for keeping up the fat balance ...

4.9 Chemistry

Young students get the task to investigate eggshells. The working sequence is shown in Table 2. They start with trying to find a solvent.

What substances are contained in egg shells?

- proteins, milk, salt, lime, same ingredients as in a tooth?

Solvent?

Ethanol: We put ethanol in a test tube; then we grinded an egg in a mortar and added the egg powder to the tube.

Result: The water became muddy and the egg powder fell to the bottom.

In vinegar bubbles are formed. When vinegar and eggshells react with each other, carbon dioxide emerges. Carbon dioxide is a gas that is heavier than oxygen. Eggshells mainly consist of calcium carbonate.

Calcium remains in the solvent. When solutions of metals are heated in a Bunsen burner flame, they give off characteristic colors. Calcium burns with a brick red flame (see Figure 7).

Eggshells consist 96% of calcium carbonate. This is the authors found on the web.

Table 2 The carbonate ion gives rise to carbon dioxide

 We broke egg shells.	 We put a burning candle into a beaker where we had grinded eggshells. Finally, we poured vinegar into the beaker.
 Vinegar and the grinded eggshells reacted with each other, carbon dioxide was formed and oxygen was forced away from the beaker.	 The candle went out.



Figure 7 The calcium ion burns with a brick red color

4.10 A foreign language

Rohlf (2009) has suggested a classroom Easter egg hunt lesson in which students hunt for hidden eggs. Students should describe the precise location of an object. Thus, they learn to express locations and use prepositions in the foreign language.

Bricolage signifies a crossing of disciplinary boundaries. In order to build up an exhaustive vocabulary in a foreign language, many perspectives must be taken into account and many disciplinary boundaries must be crossed. In this project, students were asked to find everyday words and disciplinary terms connected to each of the included disciplines. The individual vocabularies thus created could look as follows (see Table 3).

Table 3 A student's vocabulary

Everyday words	grind	zermahlen
	eggshell	Eierschale (<i>f</i>)
	vinegar	Essig (<i>m</i>)
	draw	zeichnen, malen
	animal	Tier (<i>n</i>)
	glue	Klebstoff (<i>m</i>)
	egg yolk	Eigelb (<i>n</i>)
Scientific concepts	solvent	Lösemittel (<i>n</i>)
	intersection	Schnittpunkt (<i>m</i>)
	platypus	Schnabeltier (<i>n</i>)
	globe	Globus (<i>m</i>)
	carbon	Kohlenstoff (<i>m</i>)
	diameter	Durchmesser (<i>m</i>)

By discussing and presenting all individual vocabularies, a shared vocabulary and a shared understanding of the whole project arise.

5. Results

An interdisciplinarity approach, which uses a theme as an organizing or integrating element, can show how different disciplines interrelate in the elaboration and illumination of the theme. This approach assumes a disciplinary base and strengthens the students' understanding of the disciplines themselves as they are used to pursue a given theme or topic (Ranaweera, 1990, p. 24). Some results expected of an interdisciplinary education are the abilities of transferring what the students have learned to new situations and perceive situations in their entirety.

The present results are not concentrated on a certain group of students. Each teacher has worked with his/her own students in his/her own school. Thus, no student took part in all disciplinary instructions. The collage, however, allows the students to widen their insights on the whole topic and thus add to their understanding.

6. Discussion

People shape the world by how they see it. People act in the world by how they see it. And people can reshape it depending on their individual or shared viewpoint. A key foundation for people to appreciate, especially in their communities, is that they have many viewpoints of the world and yet desire shared understanding, the capability for common action and alignment so that they can move forward to create sustainable solutions (Ranaweera, 1990, p. 23). The non-linear narrative does not present a coherent plot structure and there is a polyphony of storytellers to dispute the primacy of any one theme (Boje, 2001, p. 134).

A heap of bricks make no house. But the construction or creation of a work from a diverse range of things which happen to be available, a bricolage, is a way to learn and solve problems by trying, testing and playing around. Such notions provide the bricoleur with an understanding of the complexity of knowledge production and the interrelated complexity of both positionality and phenomena in the world. Complexity demands a rigorous mode of investigation that is capable of dealing with different complications of experience.

Integration should not be made at the expense of knowing the disciplines well. In this paper, the authors

present a conscious effort to provide students with more meaningful learning experiences. By approaching a problem or topic from the vantage point of many teachers and disciplines, students are exposed to more information and more views. The authors' objective is to provide a better understanding of how the disciplines connect with each other and the world around them.

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(Edited by Nicole and Lily)